Spin chain and ladder materials are an exciting class of compounds since the basic structural unit is similar with high-\(T_c\) superconductors. While in the superconductors \(\text{CuO}_4\) plaquettes form a 2-dimensional network, in ladders and chains materials they compose 1-dimensional arrays. \(\text{Sr}_{14}\text{Cu}_{24}\text{O}_{41}\) is one such material that exhibits both chains and ladders in subsequent layers and is particular exciting since it also shows superconductivity under pressure at a certain doping level, which is obtained by replacing La for Sr. The average valence state of Cu in \(\text{Sr}_{14}\text{Cu}_{24}\text{O}_{41}\) is 2.25 and the insulating ground state indicates that the holes are localized. A charge valence ordering at a temperature around 200 K is claimed by many different experimental techniques. However, the correlation of the holes is still uncertain. Two x-ray investigations on the structural distortion associated with the charge ordering pattern come to different conclusions. While Cox et al. find a quadrupling of the basic chain unit cell with a transition temperature at about 200 K and a very unusual temperature dependence of the Bragg reflection [1], more recently also five-fold superstructure has been proposed, which does not show any anomaly at 200 K, but is stable to high temperatures [2].

We have characterized a single crystal of \(\text{Sr}_{14}\text{Cu}_{24}\text{O}_{41}\) with high energy (100 keV) x-ray diffraction, and find a strong incommensurate modulation of the chains and ladders due to the periodicity of their neighboring layers. As shown in figure 1 in addition to the fundamental Bragg reflection originating from the ladder structure and the chain structure a number of superlattice reflections are visible at 10 K. All of them can be indexed by an ordering wave vector \(\mathbf{q}=(0,0,n*0.3013)\) with \(n\) integer. Harmonics up to the order of \(n=14\) are found. Such an ordering wave vector is simply the result of the different lattice parameters of the chain lattice and the ladder lattice. In contrast to the earlier x-ray diffraction experiments we find that both the chains and are modulated at at room temperature, with a dominating 2nd harmonic superlattice reflection. Below 200 K the intensity of higher harmonics increases indicating an additional modulation, which we believe is due to the charge ordering, that locks in the modulation present at room temperature (see figure 1).

A fascinating consequence of the charge ordering described above is the inter chain correlation. As seen in figure 2 at room temperature the chains are only weakly correlated among each other, since the reflection profile is extremely broad perpendicular to the chain direction, along \(h\) and \(k\), but well defined along the chains, that is \(l\). Thus, subsequent chains are only loosely bound to each other and perform dynamic movements that destroys the inter chain correlation. The situation becomes very different though when the holes localize in the chain structure. As seen above the holes localize only at specific chain site, namely at places were the energy due to strain is minimal. Now the chain lattice is locked to the ladder structure via charge order, and in addition the chains interact via Coulomb interactions, which dampens the dynamic behavior of the chain structure end enhances the inter chain correlation significantly. This effect can be seen by the sharp reflection profile along \(h\) and \(k\) of the (0,0,2) chain reflection at 10 K.

In summary we have reported on the charge ordering in \(\text{Sr}_{14}\text{Cu}_{24}\text{O}_{41}\) and its consequences on the inter chain correlation. We found that the origin of the superlattice reflection are not directly related to the order parameter of the charge order, rather the charges lock in into the modulated structure, which results from the intergrowth into the ladder structure. Nevertheless, the charge ordering can be established from higher Fourier components of the fundamental modulation. One consequence
Figure 1: left: Scan along (0,0,l) at 10 K and 270 K. The index l is in chain units. The position of the fundamental Bragg reflection are at l=2 for the chains and at l=1.398 for the ladders. The number and the intensity of the superlattice reflections increases at low temperature. right: Temperature dependence of selected superlattice reflections. The various orders represent different kind of distortions.

Figure 2: Reflection profile of the (0,0,2) chain Bragg reflection along h at 10 K and 270 K. At the higher temperature the chains are rather uncorrelated, as indicated by the broad reflection profile. At 10 K the amount of diffuse scattering decreases and the reflections profile becomes sharp, showing a high correlation among the chains. The inset shows scans along the chain direction l at 270 K in the tail (h=0.4) and at the peak (h=0). Both scans have approximately the same width.

of the charge ordering is a damping of the chain dynamics with an enhancement of inter chain correlations.

References
